Traumatic Brain Injury Hospitalizations of U.S. Army Soldiers Deployed to Afghanistan and Iraq

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Background: Traumatic brain injury (TBI) is a life-altering condition that has affected many of our soldiers returning from war. In the current conflicts, the improvised explosive device (IED) has greatly increased the potential for soldiers to sustain a TBI. This study's objective was to establish benchmark admission rates for U.S. Army soldiers with TBIs identified during deployment to Iraq and Afghanistan.

Methods: The study population consisted of U.S. Army soldiers deployed to Iraq and Afghanistan from September 11, 2001, through September 30, 2007. Population data were merged with admission data to identify hospitalizations during deployment. Using the international Barell Injury Diagnosis Matrix, TBI-related admissions were categorized into Type 1 (the most severe), Type 2, and Type 3 (the least severe). All analyses were performed in 2008.

Results: Of the 2898 identified TBI inpatient episodes of care, 46% were Type 1, 54% were Type 2, and less than 1% were Type 3. Over 65% of Type 1 injuries resulted from explosions, while almost half of all TBIs were non-battle-related. Overall TBI admission rates were 24.6 for Afghanistan and 41.8 for Iraq per 10,000 soldier-years. TBI hospitalization rates rose over time for both campaigns, although U.S. Army soldiers in Iraq experienced 1.7 times higher rates overall and 2.2 times higher Type 1 admission rates than soldiers in Afghanistan. The TBI-related proportion of all injury hospitalizations showed an ascending trend.

Conclusions: Future surveillance of TBI hospitalization rates is needed to evaluate the effectiveness of implementation of preventive measures.
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Introduction

Traumatic brain injury (TBI) is a blunt or penetrating injury to the head that disrupts brain function.[1,2] The CDC estimates that at least 1.4 million TBIs occur in the U.S. each year, resulting in 1.1 million emergency department visits, 235,000 hospitalizations, and 50,000 deaths.[3] The CDC also estimates that each year between 80,000 to 90,000 Americans experience TBIs that result in permanent disabilities, and 5.3 million Americans currently have a long-term need of daily assistance due to TBI.[2]

Similarly, TBI is a major health concern for the U.S. military, both in combat and noncombat settings.[4–9] The Armed Forces Health Surveillance Center (AFHSC) reported that during a 10-year period (January 1997–December 2006), 110,392 military members had at least one TBI-related medical encounter, and there were 15,732 hospitalizations with TBI-related diagnoses, with falls/miscellaneous and land transport accidents being the major causes.[5]

The nature of the current conflicts—in particular the widespread use of improvised explosive devices (IEDs)—increases the likelihood that military personnel will be exposed to incidents that can cause TBI.[6] The AFHSC reported that the largest relative increases in causes of TBI-related hospitalizations after September 2001 were related to battle casualties and weapons accidents.[5] In the

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current conflicts in Iraq and Afghanistan, exposure to blasts, motor vehicle crashes, falls, and gunshot wounds to the head or neck are the most common mechanisms of brain injury.[8]

Since September 2001, approximately 1.6 million U.S. military members have been deployed to Afghanistan (Operation Enduring Freedom [OEF]) and Iraq (Operation Iraqi Freedom [OIF]),[10] and Army soldiers compose the largest percentage of those deployed. Based on head, face, and neck injuries, it has been estimated that at least 22% of wounded soldiers evacuated from these conflicts have TBIs.[5,11,12] One recent medical study, utilizing post-deployment screening tools, concluded that 15% of returning soldiers had experienced a concussion, and one third of those reported injuries with loss of consciousness.[13] Of soldiers with TBIs evacuated to Walter Reed Army Medical Center between January 2003 and April 2005, 56% had moderate or severe (including penetrating) TBIs.[11,14]

There are a number of different systems for categorizing TBI, such as the ones used by the American Congress of Rehabilitative Medicine, WHO, and the CDC.[8] A new classification of TBI was approved in 2001 by the International Collaborative Effort (ICE) on Injury Statistics when the group finalized the Barell body region by nature of injury diagnosis matrix.[15] Documented by the CDC,[16] the matrix standardizes data selection of injury cases for epidemiologic, clinical, and management analyses.

The Barell Matrix classifies TBI into three mutually exclusive types.[15,17] Type 1, the most severe

Table 1. Demographics of deployed U.S. Army population and the subset with TBI diagnosis admissions during deployment

	Afghanistan				Iraq			
	Population (*n*=145,505)		Any TBI (*n*=207)		Population (*n*=722,474)		Any TBI (*n*=2,241)	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Gender								
Female	12,465	(8.6)	6	(2.9)	80,666	(11.2)	56	(2.5)
Male	132,882	(91.3)	201	(97.1)	641,699	(88.8)	2,185	(97.5)
Unknown	158	(0.1)	0	(0.0)	109	(0.0)	0	(0.0)
Age (years)								
<20	8,940	(6.1)	10	(4.8)	52,664	(7.3)	178	(7.9)
20–29	79,230	(54.5)	143	(69.1)	400,628	(55.5)	1,483	(66.2)
30–39	39,555	(27.2)	42	(20.3)	181,114	(25.1)	466	(20.8)
40–49	14,748	(10.1)	10	(4.8)	72,617	(10.1)	98	(4.4)
≥50	3,026	(2.1)	2	(1.0)	15,444	(2.1)	16	(0.7)
Unknown	6	(0.0)	0	(0.0)	7	(0.0)	0	(0.0)
Ethnicity								
White	98,519	(67.7)	150	(72.5)	471,896	(65.3)	1,592	(71.0)
African-American	24,522	(16.9)	16	(7.7)	133,219	(18.4)	273	(12.2)
Hispanic	13,465	(9.3)	23	(11.1)	72,865	(10.1)	224	(10.0)
Other	1,260	(0.9)	0	(0.0)	6,803	(0.9)	30	(1.3)
Unknown	7,739	(5.3)	18	(8.7)	37,691	(5.2)	122	(5.4)
Component								
Active duty	101,930	(70.1)	163	(78.7)	445,917	(61.7)	1,695	(75.6)
Reserve	14,586	(10.0)	14	(6.8)	99,046	(13.7)	123	(5.5)
National Guard	28,989	(19.9)	30	(14.5)	177,511	(24.6)	423	(18.9)
Pay grade								
Enlisted	118,487	(81.4)	185	(89.4)	619,819	(85.8)	2,097	(93.6)
Officers	25,668	(17.60)	21	(10.1)	98,333	(13.6)	141	(6.3)
Unknown	1,350	(0.9)	1	(0.5)	4,322	(0.6)	3	(0.1)
Unit category								
Combat	75,550	(51.9)	132	(63.8)	306,729	(42.5)	1,485	(66.3)
Combat service	30,954	(21.3)	31	(15.0)	167,173	(23.1)	370	(16.5)
Combat service support	29,541	(20.3)	17	(8.2)	220,164	(30.5)	308	(13.7)
Unknown	9,460	(6.5)	27	(13.0)	28,408	(3.9)	78	(3.5)

TBI, traumatic brain injury

form, includes diagnoses where "there is recorded evidence of an intracranial injury or a moderate or a prolonged loss of consciousness . . . or injuries to the optic nerve pathways. Type 2 includes injuries with no recorded evidence of intracranial injury, and loss of consciousness of less than one hour, or loss of consciousness of unknown duration, or unspecified level of consciousness." Type 3 includes diagnoses "with no evidence of intracranial injury, and no loss of consciousness."

Regardless of the classification system used, soldiers with TBI appear to represent a larger proportion of U.S. casualties in Iraq and Afghanistan compared to those in other recent conflicts.[11,12] Thus, there is a need for extensive research to estimate TBI incidence rates in both campaigns and to evaluate the impact of TBI among deployed troops. Such research can help the U.S. Army to improve measures to both diminish the risk of TBI injury and improve health policies. These policies may include better identification of TBI and improved provision of medical resources to care for TBI cases. The purpose of this study was to establish benchmark admission rates at U.S. Army medical treatment facilities for soldiers with TBIs identified during deployment to Iraq and Afghanistan.

Methods

Data for this study were obtained from several existing databases. Population data for soldiers deployed in Afghanistan and Iraq from the beginning of the campaigns (September 11, 2001 in Afghanistan; October 1, 2002 in Iraq) through September 30, 2007, including demographics and dates of arrival and departure from theater, were provided by the Defense Manpower Data Center. Inpatient healthcare data for these soldiers during their deployments were obtained from the Standard Inpatient Data Record (SIDR) database maintained by the Army's Patient Administration Systems and Biostatistics Activity. Standard Inpatient Data Records are the official electronic records of hospitalizations in Department of Defense (DoD) medical facilities worldwide. Data on helmet use were obtained from the Defense Casualty Information Processing System (DCIPS) maintained by the Army's Casualty and Memorial Affairs Operations Center. The DCIPS database documents each U.S. casualty including information on circumstances of the incident. Causal agent, manner of intent, and mode of transportation were obtained from the Joint Theater Trauma Registry (JTTR) developed by the Center for Army Medical Department (AMEDD) Strategic Studies[18] and maintained by the U.S. Army Institute of Surgical Research.

Admissions included in this study were from Army facilities located both in-theater and in Europe and the U.S. if the soldiers were evacuated from theater. Episodes of care were created from the admission records so that if a soldier moved from one facility to another for additional care, there would be only one record per casualty incident. Hospitalizations within 10 days of each other were one episode. TBI episodes were identified by ICD-9-CM diagnosis codes using the Barell Matrix classification scheme.[16] Diagnosis codes were classified into the three TBI types as follows:

- Type 1 (the most severe): 800, 801, 803, and 804 (plus fourth and fifth digits: 0.03–0.05, 0.1–0.4, 0.53–0.55, 0.6–0.9); 850 (0.2–0.4); 851–854; 950 (0.1–0.3).
- Type 2: 800, 801, 803, and 804 (plus 0.00, 0.02, 0.06, 0.09, 0.50, 0.52, 0.56, 0.59); 850 (0.0, 0.1, 0.5, 0.9).

Table 2. Distribution of TBI hospitalizations[a] by location and injury type

Location/injury type	TBI[b]							
	Type 1		Type 2		Type 3		Any	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Afghanistan								
Battle injury	35	(40.7)	48	(31.8)	3	(37.5)	85	(35.9)
Nonbattle injury	51	(59.3)	103	(68.2)	5	(62.5)	152	(64.1)
Total	86		151		8		237	
Iraq								
Battle injury	751	(60.7)	660	(46.9)	55	(44.0)	1399	(52.6)
Nonbattle injury	487	(39.3)	747	(53.1)	70	(56.0)	1262	(47.4)
Total	1238		1407		125		2661	
Overall								
Battle injury	786	(59.4)	708	(45.4)	58	(43.6)	1484	(51.2)
Nonbattle injury	538	(40.6)	850	(54.6)	75	(56.4)	1414	(48.8)
Total	1324		1558		133		2898	

[a]During deployment, for U.S. Army soldiers deployed between September 11, 2001, and September 30, 2007.
[b]Type 1 TBI (most severe), Type 2, and Type 3 (least severe) refer to Barell Injury Matrix categories.[15]
TBI, traumatic brain injury

- Type 3 (the least severe): 800, 801, 803, and 804 (plus 0.01, 0.51).

The first eight diagnoses from each admission were checked for presence of a TBI diagnosis. Each episode was classified as to the presence or absence of one or more TBI diagnoses ("Any TBI") and the presence or absence of each type of TBI. In analyses, an episode could be counted in more than one category, but only once within each category. For example, suppose an episode consisted of two admissions (first admission: one Type 1 diagnosis, one Type 2 diagnosis; second admission: two Type 2 diagnoses). Then the episode would count once in "Any TBI," once in Type 1 TBI, and once in Type 2 TBI.

Variables included gender (male, female); age group (< 20, 20–29, 30–39, 40–49, 50+); ethnicity/race (white, African American, Hispanic, other); rank (enlisted, officer); unit category (combat, combat support, combat service support); army component (active duty, National Guard, Reserve); and for OIF only, campaign phase based on deployment dates (buildup: September 1, 2002, through March 19, 2003; combat: March 30, 2003 through April 30, 2003; stabilization: May 1, 2003, through September 30, 2007). Episodes were summarized by operation (Afghanistan, Iraq); TBI category (Type 1–Type 3, Any); and injury type (battle injury, nonbattle injury). Battle injuries were identified by the North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) 2050 trauma and cause-of-injury codes.[19] Reasons for admission for both battle and nonbattle injuries were determined by ICD-9-CM principal diagnosis codes.

Helmet-use data from the DCIPS file specified whether a helmet was worn, not worn, or unknown during the incident that caused the TBI. Data on helmet use in the DCIPS casualty records was very sparse prior to April 2005, and analyses were restricted to battle injury episodes occurring from April 2005 through September 2007. Direct mechanism (e.g., blunt, explosion, penetrating) of injury and causal agent categories (e.g., munitions and explosives, motor vehicle crashes) from the JTTR data were also added to the episode of care records and summarized by theater and TBI category.

Episodes were summarized by first date of admission and merged with daily deployed soldier population counts to obtain TBI and total injury occurrence rates. All rates were determined as the number of episodes per 10,000 soldier-years.

Risk analyses were conducted using multivariate Poisson regression for Types 1–3 and "Any TBI" for each campaign. Factors examined included gender, age group, ethnicity/race, rank, unit category, component, and campaign phase (Iraq only).

All data analyses were performed using SAS version 9.1.3 software. Relative risks were determined using the SAS GENMOD procedure. In all analyses, p-values less than 0.05 were considered significant.

Results

Of 145,505 individuals deployed to Afghanistan, 0.14% had one or more TBI-related hospitalizations during their deployments (Table 1). In Iraq, 0.31% of 722,474 deployed soldiers were hospitalized with TBI diagnoses during deployment. Although men were approximately 90% of deployed soldier populations, they accounted for 97% of TBI-related hospitalizations in both theaters of operation. Soldiers aged 20–29 years represented about 55% of both deployed populations, but accounted for more than 66% of those hospitalized with TBI in both campaigns. Also in both theaters, beginning with those aged 20–29 years, there was an

Table 3. Direct mechanism of injury for TBI hospitalizations[a] matched to JTTR records

Location/direct mechanism	TBI[b]							
	Type 1		Type 2		Type 3		Any	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Afghanistan								
Explosion	23	(65.7)	19	(34.5)	1	(25.0)	42	(46.7)
Blunt	4	(11.4)	21	(38.2)	1	(25.0)	24	(26.7)
Penetrating	4	(11.4)	5	(9.1)	1	(25.0)	10	(11.1)
Other	4	(11.4)	10	(18.2)	1	(25.0)	14	(15.6)
	35	(100.0)	55	(100.0)	4	(100.0)	90	(100.0)
Iraq								
Explosion	478	(67.8)	334	(58.1)	56	(64.4)	829	(63.9)
Blunt	94	(13.3)	154	(26.8)	21	(24.1)	248	(19.1)
Penetrating	116	(16.5)	22	(3.8)	9	(10.3)	143	(11.0)
Burn	1	(0.1)	1	(0.2)	0	(0.0)	1	(0.1)
Other	16	(2.3)	64	(11.1)	1	(1.1)	77	(5.9)
	705	(100.0)	575	(100.0)	87	(100.0)	1298	(100.0)

[a]During deployment, for U.S. Army soldiers deployed between September 11, 2001, and September 30, 2007.
[b]Type 1 TBI (most severe), Type 2, and Type 3 (least severe) refer to Barell Injury Matrix categories.[15]
JTTR, Joint Theater Trauma Registry; TBI, traumatic brain injury

overall trend of decreasing incidence of TBI with increasing age group. Another similarity found in both theaters was that enlisted soldiers accounted for an 8% greater proportion of total TBI admissions compared to their respective proportions of the deployed populations.

When TBI episodes were summarized by injury type (Table 2), the majority of total admissions (over 51%) were related to battle injuries. However, TBI hospitalizations demonstrated different profiles in each theater. Battle injury admissions associated with TBI Type 1 accounted for 61% of TBI episodes in Iraq and only 41% in Afghanistan. Type 2 TBI admissions were related mostly to nonbattle injury episodes (Afghanistan: 68%; Iraq: 53%).

When the JTTR data were merged with the TBI episodes, matches were obtained for 1388 (48%) TBI episodes (Iraq: 1298 [49%]; Afghanistan: 90 [38%]; Table 3). Distribution of the direct mechanism of injury was fairly consistent across TBI categories in Iraq, with explosions accounting for the majority of all TBIs, from 58% of Type 2 to as much as 68% of Type 1. Results in Afghanistan were more variable, with explosions accounting for 66% of Type 1 TBI, but only 47% of Any TBI and less than 35% of Type 2 TBI episodes. About two thirds of Type 1 episodes were due to munitions and explosives in both campaigns, followed in Afghanistan by firearms (11%) and falls (11%) and in Iraq by firearms (17%) and motor vehicle crashes (9%). Munitions and explosives also accounted for the majority of the other TBI categories in Iraq. However, in Afghanistan, munitions and explosives, although the leading causal agent, accounted for only 35% of Type 2 and 47% of Any TBI. In both campaigns, motor vehicle crashes were the second leading causal agent for Type 2 (Afghanistan: 26%; Iraq: almost 18%). When comparing direct mechanism profiles for Any TBI admission, 64% and 47% were caused by explosion (Iraq and Afghanistan, respectively), 19% and 27% by blunt mechanism of injury, and 11% by penetrating direct mechanism in both campaigns.

A profile of helmet use by TBI category and theater is presented in Table 4. Recall that the sum of the three TBI types can be greater than the number of Any TBI (which is the number of unique TBI episodes). During the period when helmet-use data were populated (April 1, 2005, to September 30, 2007), there were 1047 TBI battle injury episodes of care. The results show that in both theaters, regardless of TBI category, the majority of those sustaining TBIs were wearing their helmets at the time of the injury incident. In fact, at least 77% of soldiers sustaining Any TBI were wearing their helmets when injured (Afghanistan: 77%; Iraq: 79%).

Relative risk analyses for TBI by campaign were performed, and results for Any TBI are summarized in Table 5. In Afghanistan, enlisted soldiers experienced a higher risk of TBI-related hospitalizations than officers (2.5 for Type 1 to 1.5 for Type 2). National Guard soldiers demonstrated significantly lower risk than active duty soldiers (approximately one half the risk for TBI Type 2 and 21% less risk for TBI Type 1); and those personnel assigned to combat units

Table 4. Wearing of helmet as reported in DCIPS, matched to TBI battle injury hospitalizations[a]

Location/helmet wear	TBI[b]							
	Type 1		Type 2		Type 3		Any	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Afghanistan								
Worn	17	(70.8)	30	(83.3)	1	(50.0)	48	(77.4)
Not worn	3	(12.5)	2	(5.6)	0	(0.0)	5	(8.1)
Unknown	4	(16.7)	4	(11.1)	1	(50.0)	9	(14.5)
	24		36		2		62	
Iraq								
Worn	372	(78.3)	424	(80.0)	22	(66.7)	779	(79.1)
Not worn	45	(9.5)	23	(4.3)	3	(9.1)	67	(6.8)
Unknown	58	(12.2)	83	(15.7)	8	(24.2)	139	(14.1)
	475		530		33		985	
Total								
Worn	389	(78.0)	454	(80.2)	23	(65.7)	827	(79.0)
Not worn	48	(9.6)	25	(4.4)	3	(8.6)	72	(6.9)
Unknown	62	(12.4)	87	(15.4)	9	(25.7)	148	(14.1)
	499		566		35		1047	

[a]Limited to TBI battle injury hospitalizations which occurred between April 1, 2005, and September 30, 2007.
[b]Type 1 TBI (most severe), Type 2, and Type 3 (least severe) refer to Barell Injury Matrix categories.[15]
DCIPS, Defense Casualty Information Processing System; TBI, traumatic brain injury

Table 5. Relative risks (RRs) of hospitalization for any TBI during deployment[a]

Characteristic	Afghanistan RR[b]	Afghanistan (95% CI)	Iraq RR[b]	Iraq (95% CI)
Gender				
Male	1.00	(baseline)	1.00	(baseline)
Female	**0.37**	(0.24, 0.57)	**0.30**	(0.26, 0.36)
Age (years)				
<20	1.00	(baseline)	1.00	(baseline)
20–29	**0.57**	(0.48, 0.68)	**0.79**	(0.74, 0.84)
30–39	**0.37**	(0.26, 0.51)	**0.51**	(0.45, 0.57)
40–49	**0.32**	(0.15, 0.68)	**0.40**	(0.29, 0.55)
≥50	—	—	**1.48**	(1.35, 1.62)
Race/ethnicity				
White	1.00	(baseline)	1.00	(baseline)
Black	**0.48**	(0.37, 0.63)	**0.68**	(0.63, 0.73)
Hispanic	**1.37**	(1.08, 1.75)	0.97	(0.88, 1.07)
Grade				
Officer	1.00	(baseline)	1.00	(baseline)
Enlisted	**1.86**	(1.46, 2.38)	**1.94**	(1.76, 2.15)
Component				
Active duty	1.00	(baseline)	1.00	(baseline)
National Guard	**0.64**	(0.52, 0.78)	**0.71**	(0.66, 0.75)
Reserve	1.01	(0.76, 1.34)	**0.55**	(0.49, 0.62)
Unit type				
Combat	1.00	(baseline)	1.00	(baseline)
Combat support	**0.62**	(0.51, 0.76)	**0.62**	(0.57, 0.66)
Combat service support	**0.44**	(0.34, 0.57)	**0.38**	(0.35, 0.41)
Campaign phase[c]				
Stabilization	—	—	1.00	(baseline)
Build-up	—	—	**0.33**	(0.29, 0.38)
Combat	—	—	**0.51**	(0.46, 0.57)

[a]U.S. Army soldiers deployed between September 11, 2001, and September 30, 2007
[b]Highlighted values imply significant relative risk at the 0.05 level of significance.
[c]Applicable only to Iraq
CI, confidence interval; TBI, traumatic brain injury

presented greater risk than those in combat support or combat service support units. With regard to age, there was a trend of decreasing risk with increasing age.

One sees many parallel results within the Iraq campaign. Enlisted personnel experienced from 1.5 to almost 3 times the risk compared to officers. National Guard and reservists demonstrated lower risk than active duty (30% and 45% less risk, respectively). Those serving in combat units were at greatest risk relative to those in combat support and combat service support units. Finally, there was a general pattern of decreasing risk with increasing age for Types 1 and 2, with the notable exception for those in the 50+ category. In addition, in Iraq an increasing trend in TBI risk was associated with the phase of the campaign, with the stabilization phase having the greatest risk.

In general, the incidence of TBI hospitalizations during deployment increased over time. Table 6 presents yearly and overall admission rates per 10,000 soldier-years for the most severe form of TBI (Type 1) and for the occurrence of any TBI-related hospital episodes of care (Any TBI). Overall TBI-related admission rates in Iraq were significantly higher than in Afghanistan (Poisson regression, $p<0.0001$). For both Iraq and Afghanistan, Any TBI admission rates and Type 1 TBI rates were positively correlated with time (Iraq: Any TBI, $r=0.81$, $p=0.05$; Type 1, $r=0.70$, $p=0.06$; Afghanistan: Any TBI, $r=0.88$, $p=0.008$; Type 1, $r=0.74$, $p=0.058$). In both theaters of operation, there was a major increase in Any TBI rates in 2004 compared to previous years, with a sevenfold increase in Afghanistan and a twofold increase in Iraq. Rates then remained relatively constant until 2007, when an approximately twofold increase occurred in both Afghanistan and Iraq.

Table 6. Type 1 TBI[a] and any TBI hospitalization rates[b] per 10,000 soldier-years

Year	Afghanistan		Iraq	
	Type 1	Any TBI	Type 1	Any TBI
2001	3.7	3.7	—	—
2002	4.4	12.6	0.0	22.8
2003	2.9	7.9	10.4	19.3
2004	10.7	26.4	23.0	39.6
2005	11.1	28.4	17.9	37.6
2006	6.7	24.5	17.7	42.4
2007	21.1	56.6	31.3	77.9
Overall	8.9[c]	24.6[d]	19.4[c]	41.8[d]

[a]Barell Injury Matrix category for more severe TBI[15]
[b]During deployment, for U.S. Army Soldiers deployed between September 11, 2001, and September 30, 2007
[c]Overall hospitalization rate for Type 1 TBI was significantly higher in Iraq compared to Afghanistan (Poisson regression, $p<0.0001$).
[d]Overall hospitalization rate for Any TBI was significantly higher in Iraq compared to Afghanistan (Poisson regression, $p<0.0001$).
TBI, traumatic brain injury

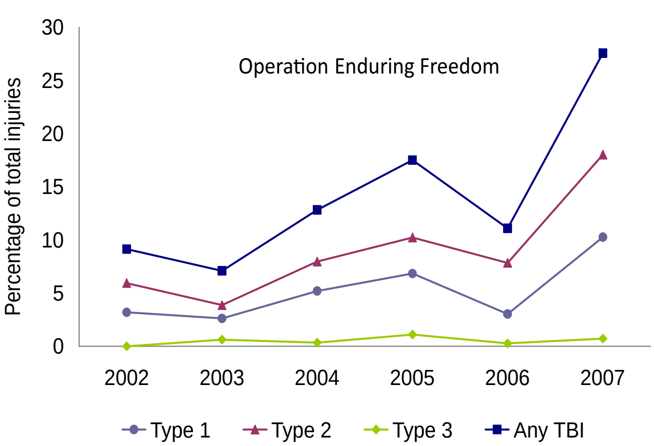
In examining population-based rates of TBI occurrence, the rates for all injury occurrences were also reviewed, and increasing trends in both were observed. In order to determine the relative increase in TBI compared to all injuries, TBI rates per 10,000 soldier-years as a percentage of all injury rates per 10,000 soldier-years were examined (Figure 1). In both Afghanistan and Iraq, there were marked increasing trends in Types 1 and 2 and Any TBI as percentages of all injuries, with sharp increases from 2006 to 2007. Type 3 rates as percentages of all injury rates had relatively flat slopes. When examining the Iraq plot, one notes the continued increase with time of the Any TBI and Type 3 categories and the sharp increases in Any TBI and Types 1 and 2 from 2006 to 2007. In Afghanistan sharp increases occurred from 2006 to 2007 in Any TBI and Types 1 and 2.

Discussion

Traumatic brain injury has been recognized as the "signature wound" of the current conflicts in Iraq and Afghanistan.[20,21] Recent surveys indicate that approximately 17%–22% of returning soldiers could have TBIs.[5,7,11,12]

Several papers have been published in recent years that concentrated on post-deployment detection and treatment of primarily mild TBIs.[6,13,22,23] In contrast, this study sought to establish baseline data on the generally more severe TBI-related hospitalizations of soldiers during their deployments. The study limitations include the use of secondary data, the exclusion of undiagnosed TBIs, and the lack of data regarding helmet use prior to April 2005. The episodes of care span admissions at combat support hospitals in the theater through evacuations to Army facilities in Germany and the U.S. A 10-year surveillance (1997–2006) of TBI occurrence in U.S. military worldwide (both battle and nonbattle injury) reported an overall Army rate of 93.9 medical encounters (outpatient and hospitalizations) for TBI per 10,000 soldier-years.[5] Looking at TBI hospitalizations during deployment, the current study found an overall rate of 24.6 for Afghanistan and 41.8 for Iraq per 10,000 soldier-years. In both theaters, there was an increase in both Type 1 and Any TBI rates from 2006 to 2007.

Based on the analysis, TBI episodes in 2007 constituted similar percentages of all injury hospitalizations in both Iraq and Afghanistan (27% and 28%, respectively.) These percentages represented significant increases over levels from the first full



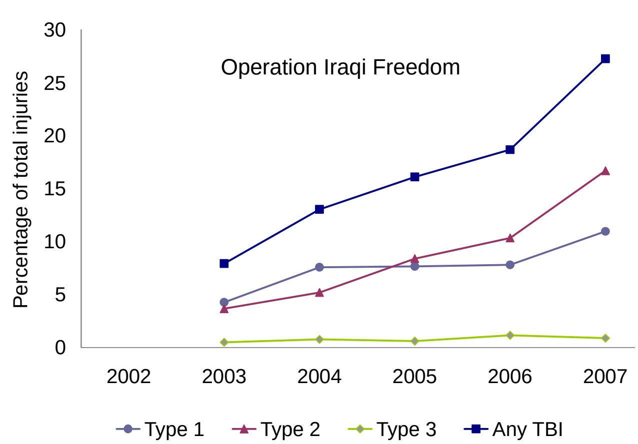


Figure 1. Tramatic brain injury (TBI) hospitalization episode rates as percentages of total injury rates
Note: All rates were expressed as per 10,000 soldier-years.

year in both campaigns (19% increase in Iraq and 18% in Afghanistan). The ascending trend in the TBI-related proportion of all injury hospitalizations may be a response to increased awareness and detection of TBI. For example, the Defense and Veterans Brain Injury Center (DVBIC) developed two screening tools: the Military Acute Concussion Evaluation (MACE) for in-theater screening and the Brief TBI Screen (BTBIS) for post deployment screening, which have improved the proper diagnosis and treatment of TBI.[24]

As a result of this study, several potential risk factors for TBI-related, in-theater hospitalization were identified. In both campaigns, female soldiers demonstrated about a 70% decreased risk of any TBI admission, but it is not known whether this lower rate is indicative of nondeployment to combat units, the use of more protective equipment, or greater caution by female soldiers. Additional studies are needed to answer these questions. As expected, combat support and combat service support units experienced much lower risk of TBI hospitalizations than combat units. Findings indicate a decreased trend of TBI risk with soldier's age, potentially due to the greater caution that comes with experience. Future research should examine if the above relationship is a function of years of service.

An analysis of helmet use revealed that more than 70% of soldiers with TBI (all categories except for Type 3) were wearing head protection at the time of the injury incident. In Afghanistan, 12.5% of soldiers sustaining a Type 1 TBI were not wearing a helmet; similarly, 9.5% in Iraq. Follow-up analysis as to why helmets were not used is recommended.

As expected with deployed soldiers, the majority of Type 1 TBI cases were caused by explosives (Afghanistan: 66%; Iraq: 68%). When comparing direct mechanism profiles for any TBI admission, 64% and 47% are caused by explosion (Iraq and Afghanistan, respectively). Increased numbers of IEDs in recent years are probably primarily responsible for the above statistics. Better methods of prevention need to be explored to protect soldiers more effectively from future IED attacks. In conclusion, the U.S. Army faces major challenges in the prevention, identification, and treatment of TBIs to decrease these rates. To measure the success of the Army's future preventive interventions, we propose ongoing surveillance to monitor TBI hospitalization rates in-theater.

The opinions expressed herein are those of the authors and do not reflect the official policy or position of the Department of the Army, the Department of Defense, or the U.S. Government.

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